STUDY OF WELDING ECONOMY AND IMPROVE PRODUCTIVITY OF (2205) DUPLEX STAINLESS STEEL MATERIAL

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Abstract: Welding input parameters and skill of welder plays a very important role in determining the quality of a weld joint. Duplex stainless steels (DSS) are two-phase alloys consisting of approximately equal proportions of 50 % ferrite (δ) and 50% austenite (γ) phases. The welding DSS is more often referred to as a skill based activity when compared to scientific activity and it is an interdisciplinary subject with convergence of different stream of basic science like physics and chemistry in addition to engineering subjects like mechanical, electrical, metallurgy and chemical. This study deals with economy of welding on DSS material, which helps the industries to reduced input cost and improve profits. To improve the productivity and quality of weld, the welding process should follow the best terminologies. It also depends upon the usage of essential welding parameters like, electrode diameter, wire diameter, current, voltage, shield gas, arc time, polarity, penetration, deposition rate and their effect on weld metal. This paper presents a comprehensive literature of optimum methods in the area of welding. This review was classified according to the major process parameters for different welding processes on Duplex Stainless Steel. Additionally few tips will enlighten the ways to improve the productivity and quality of weld.

Keywords: duplex stainless steel, welding economy, productivity.

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1. INTRODUCTION

Duplex stainless steels are characterized by well controlled ferrite/austenite microstructure and are well known for their excellent corrosion resistance and higher strength compared with common austenitic stainless steels. The problems related to duplex stainless steels (DSS) are mostly associated with the heat-affected zone (HAZ) and not with the weld metal. The HAZ problems are not hot cracking but loss of corrosion resistance and toughness. The welding characteristics of duplex stainless steels are much more sensitive to minor variations in chemistry or processing than austenitic stainless steels. No amount of procedure is effectively qualified if the material is not thoroughly clean before welding. Duplex stainless steel is a common structural material in the oil and gas industries, and has special application in chemical, wastewater and marine engineering fields as well. The phase balance of the weld metal is critical to maintain the original chemical and physical properties of duplex stainless steel. The welding techniques that control the ferrite and austenite content of the weld metal are very important, according to Tsann-Shyi Chern [1]. The knowledge, the capabilities, the attitude, the focus on objectives, the effectiveness, the dedication, the togetherness or team work and the application of their minds towards attaining the goals of the organization decides the effective utilization of resources which results in business excellence. An organization can earn more profit only when it can keep the cost lesser than the market price. In the competitive environment the companies are in a fix to accept the price offered by the market. The buyer's market exposes the organizations to intense competition. When, it is happening in the opened up economy, the competition becomes more severe as it comes from all corners of the globe, especially from the advanced countries. Hence, the focus should be on productivity rather than mere production. This has been reported in AWS CWS manual [2]. The advantages of productivity are not only restricted to the boundaries of the organization but also extended to the development of the whole nation. Improved productivity of DSS material leads to the improved quality, price reduction, more revenue and standard of living.

By Omyma Hassan [3] in comparison to austenitic stainless steels, precipitation of sigma phase in 2205 Duplex stainless steels (DSS) occurs, within the ferrite phase at shorter time, at higher temperatures and with large volume fractions. Table 1 shows the chemical composition of DSS (2205) material.

Table 1: Chemical composition of 2205 duplex stainless steel (DSS)

Element	C	Si	Mn	Ni	Mo	Cr	P	S	Cu	N
2205 DSS (wt %)	0.03	0.36	1.77	5.70	2.258	22.05	0.018	0.015	0.2	0.14

2. WELDING PRODUCTIVITY

Welding is the most widely used material joining process being used in many fabrication industries. Ongoing developments in the field of Duplex stainless steel (DSS) material joining, particularly in welding, the widely used process in manufacturing industries are Shield Metal Arc Welding, Submerged Arc Welding, Tungsten Inert Gas Welding and Metal Inert Gas welding techniques. The development of newer materials and newer applications for exiting materials make the manufacturing industries to change from the traditional methods of production. The cost of DSS welding is especially important when the cost itself is large or when represent a significant proportion of the total cost of a project on contract or when expressed on an annual basis. The following are the operation to be considered to improve productivity for DSS Material:

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1. Preparation of DSS material for welding like marking, shearing, cutting, edge preparation, machining, gas cutting.
2. Setting up the components for DSS welding like jigs, fixtures, positioners, manipulators, clamps, cleaning the fusion areas by grinding.
3. Actual welding i.e., dressing the welds, chipping, grinding, machining after welding DSS.
4. Inspection of the welds, Visual, destructive and non-destructive testing.

Table 2: Comparison of welding cost with other costs

S.No.	Type of process	Cost % for processes
1	Preparation	10%
2	Assembly	05%
3	Preheating	05%
4	Welding	59%
5	Dressing	05%
6	PWHT	10%
7	Inspection	05%

Table 2 show the comparison of welding cost with other costs for duplex stainless steel materials.

West Germany and Britain National Productivity Council, 38, Golf Links, New Delhi [4] have reported that the welding is the core operation of the fabrication, then productivity of any fabrication shop is directly affected by the productivity of welding operation. Minimizing the waste component in all the resources involved in welding, which are detailed as follows:

1. Man: The welding supervisor, the designer, the welding engineer, the NDE (Non Destructive Equipment) inspector to a large extent and people from other departments of the organization who deal with welding.
2. Machine: power source, NDE system, clamping, accessories are forming part of this segment.
3. Materials: Base metal, filler metal, The NDE consumables.
4. Methods: The specification, procedure and practices are coming under the methods domain.
5. Money: The cost and outcome of automation, the investments, the working capital.

There are many welding practices like Shielded Metal Arc Welding, Semi automatic and automatic submerged Arc welding, Semi automatic GMAW, GTAW, Electro slag welding etc…But among all these practices the Shielded Metal Arc Welding (SMAW) is one of the most widely employed. The Objectives for effective utilization of the resources:

1. Avoiding over size welds.
2. Rejections and scraps.

3. Minimizing weld time, work effect, motion and delay.

The Objective will affect the following characteristics of DSS weld process:

1. Operation factor, Arc time, Non arc time.
2. Deposition rate, Requirement of welding consumables, fixturing.
3. Mechanization and automation.
4. Improved welding system.
5. Recording and feedback.

Easwaran et.al [5] has proposed a hot wire Gas Tungsten Arc Welding process is the best way to improve the productivity. Lower deposition is one of the limitations of conventional GTAW process. Development of suitable power source for main arc, hot wire power source, wire feeder, torch for hot wire GTAW and most importantly, avoidance of arc deflection due to hot wire has been the focus area of research in GTAW. With increasing application for newer breed of creep strength enhanced ferrite steels and Ni-base alloys for high temperature application, the technology offers the best solution for tube , pipe joints and also in the case of dissimilar weld joints. Shielded gas mixture such as 80 % Argon + 20 % CO_2 is commonly used for GMA welding of carbon and low alloy steels. However, the shielding gases used for Duplex stainless steels differ from those used in GMAW of unalloyed steels as they contain less active gases, such as oxygen and carbon dioxide [6, 7]. After welding stainless steels with particular low carbon contents, the weld metal should not exceed 0.03% of carbon. Special gas mixture will be used to weld DSS Materials for improvement in productivity and quality of weld metal.

2.1 Terminologies

The following are the terminologies and techniques associated for improving Duplex Stainless Steel welding productivity:

1. Weld Metal Volume
2. Deposition rate and Efficiency.
3. Filler metal Consumption.
4. Total Labour time, arc time, Non arc time.
5. Operation factor.
6. Arc time per weldment.

In Welding Engineers Hand Book [8] it was published that the weld metal volume is the amount of filler metal consumed in making welds. The area of cross section of the edge preparation when multiplied by the length would give the volume for which the weld metal has to be deposited.

Deposition Weight: This indicates the weight of weld metal deposited in the intended groove or location for effecting the joint.

Deposited Weight = Specific density of weld metal (ρ) x Deposited weld metal Volume. (1)

From the weld metal weight other welding details like total arcing time, total labour time, filler metal consumption can be arrived.

Deposition rate: The deposition rate is the weight of the weld metal deposited per unit time (gms/min). It depends on the type of the electrode, size of electrode and the current used. The deposition efficiency for various types of processes has show in the table: 3.

Deposition Rate = The amount of filler metal wire/ electrode deposit in one hour. (2)

Deposition Efficiency:

$$\eta = \frac{\text{Weigth of weld Metal Deposited}}{\text{Weight of filler Material Used}} \text{ X } 100 \quad (3)$$

Table 3: Deposition Efficiency for various Processes

	Deposition Efficiency: η for various Processes	
1	SMAW	55.55%
2	GMAW (wire)	90.97%
3	GMAW (Coated wire)	80.90%
4	SAW	97%

Filler Metal Consumption: It is the weight of filler material required to make the given size of the weld.

Total Labour Time = Total Non-Arc Time + Total Arc Time (4)

$$\text{Total Arc Time} = \frac{\text{Weigth of weld metal deposited}}{\text{Deposition Rate}} \quad (5)$$

Total Non-Arc Time: It is the time for which the welder is not able to do arcing. The following are the unproductive timing has to be reduced.

1. Loading and unloading parts
2. Time between each passes.
3. Alignment and initial equipment setup.
4. Cleaning during welding.
5. Grinding interpass and final.
6. Inspection.
7. Heat treatment when required.

$$\text{Operating Factor} = \frac{\text{Total Arc Time}}{\text{Total Arc Time+Tatal Non Arc Time}} \quad (6)$$

Every effect should be made to increase the Operation Factor, because it reduces the waste component in time. The welders performance determines the appearance and the quality of the weld. Work should be planned and positioned to minimize physical strain and ensure maximum comfort and safety. It may be the economy which is to provide the welder with a helper who can set up jobs for him. Every operation the welder has to perform, apart from that the actual welding reduces the arc time, and it naturally reduces the operation factor. It is not unusual for a welder to spend 50 % of his time in setting up a job. If he is provided with a helper and an additional jig, his production is doubled and at the same time the cost is reduced simultaneously.

Time standards for manual arc welding [9] have reported that the Arc time per weldment is the amount of time the welding arc is maintained while making a specific length of weld. Developments in welding technology and automation help the industries to improve its productivity and economy. Recent developments in design and operation have put to lot of challenges in front of welding engineers which has led to many innovations such as introducing of new terminology or variants of processes, new techniques, mechanization and several others. The equipment used while welding a high thickness welds, adoption of narrow gap Submerged Arc Welding technique provides great advantage in terms of reduction in welding consumables and cycle time. Dileep Kulkarni et al [10] have presented the use of industrial robotic welding in heavy industry for mass production e.g. automobile sector. However, robotic welding can be applied in ship building as well as in pressure vessel manufacture. Apart from panel welding applications at shipyard, robotic welding is been used for overlaying critical components of pressure vessels

2.2 Avoiding Over Size DSS Welds

The over sized welds leads to more arc time, increased filler material addition, more heat input, more power consumption and affects the productivity as well as quality of the DSS weld by increasing the residual stress in the weldment. The increased weld size will result in more reinforcement which becomes a point for stress concentration and may lead to failure of the DSS joint [11, 12]. The following factor s will be responsible for over sized welds:

1. The fit up of the job, if it is done with mismatches, large root gap will require more deposition and result in over sized welds.
2. The welder deposits welds large than the size required by the design specifications (as indicated in the drawing), by following improper welding parameters.
3. The designer fails to specify the weld sizes based on current load and service conditions for the material being used.

2.3 Avoiding or Minimizing Rework, Rejects and Scraps

The major problems that are faced by the welding engineer not only affects the arcing time but also the non arcing time, offset the production plan, increase the cycle time and also affects the quality of the products. The following are the essential welding variables for duplex stainless steel.

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1. Amperage or Wire Feed Speed
2. Arc Voltage
3. Travel speed
4. Electrode Extension.
5. Transverse Gun Angle.
6. Travel Angle.
7. Electrode Position.
8. Polarity (Inductance in the case of GMAW).

Arc voltage and Wire Feed Speed are the two variables which must always be in balance. From weld quality standpoint, an arc voltage that supports given amperage is need to avoid welding defects such as undercut and cold lap. Travel speed is determined by the weld size and the parameters like voltage and current. If the speed is very slow, weld joint will be over sized or it will have rollover resulting in cold lap. If the travel speed is too fast, the weld will be undersized and defective.

Electrode Extension is also known as contact tube to work distance. This applies to arc-welding processes with continuous wire feed and refers to the portion of the contact tube-to—work-distance between the end of contact tip and welding arc. Long extension results in reduction in temperature of base metal and reduces penetration to an unacceptable level or cause lack of fusion. In too short electrode extension excessive heat for the wire feed speed will go into base metal and result in excessive melting and even burn through the base metal. Transverse Gun Angle is an angle with the work piece in a plane perpendicular to the direction of travel and this is know as transverse gun angle. It helps the welder to control the bead shape, fillet weld leg size and weld bead. Improper transverse angle control lead to defective weld condition requires rework. Travel angle is the angle formed by the wire with the work piece in a plane parallel to the direction of travel. Table 4 indicates the effects push and pull angles.

Table 4: Effect of Drag / Push Angles

Feature	Push	Drag
Travel speed	Very fast	Very slow
Spatter	More	Less
Penetration	Slightly less	Slightly more
Bead Shape	Flatter	More Convex

Reports of the welding studies by BHEL [13] has presented that the welder should have control over electrode position to prevent roll-over, undercut, slag entrapment, incomplete fusion and incomplete penetration. Direct current Electrode Negative Polarity and Direct current Electrode Positive polarity are used for Direct Current (DC) welding. The change in polarity will have affect in melting, deposition rate, arc starting, arc blow sensitivity as well as penetration. The following factors could be affecting the goal of avoiding or minimizing reworks, rejects and scraps.

1. Lack of Workmanship standards and training.
2. Lack of proper shop surveillance by welders and supervisor.
3. Lack of understanding by welder and supervisors of the essential welding variables and their effects on weld quality.

2.4 Minimizing Arc Time per Weldment

To achieve the maximum deposition rate, correct ratio of wire, feed rate the amperage and arc time per weldment should be maintained. By reducing the arc time per weldment, more length of weld can be made in the available arc time. The Following tables indicate the typical benefits of using the higher range of amperage and voltage for enhanced deposition rate. Tables 5 and 6 indicate the typical benefits of using the higher range of amperage and voltage for enhanced deposition rate.

Table 5: Low hydrogen, iron power electrodes (E 7018)

Electrode Diameter	Amperage	Voltage	Deposition Rate (Kg/hr)
2.5 mm	70-110	20-30	0.60-0.80
3.15 mm	110-140	20-30	1.05-1.23
4 mm	140-200	20-30	1.25-1.95
5 mm	200-300	20-30	2.18-2.54

Table 6: Spray transfer mode 98 % ar + 20 % co_2(ER 70 SX).

Wire Diameter	Amperage	Wire Feed Per mint	Voltage	Deposition Rate in Kg/hr.
0.8 mm	180-230 A	10 m-14 m	25-27	2.87-3.63
1.2 mm	260-340 A	8 m-13 m	25-30	3.63-5.90
1.6 mm	290-400 A	4 m- 7m	26-36	4.00-6.36

Kuang-Hung and Tseng [14] have investigated that to improve high quality welds and stable weld arc, the activated TIG process requires large diameter electrodes to support a given level of the weld current.TIG welding with SiO_2 and MoO_3 fluxes achieves an increase in weld depth and a decrease in bead width, respectively. The activated TIG welding can increase the arc voltage, the amount of heat input per unit length in a weld is also increased, and therefore the delta-ferrite content in weld metal will be increased.The addition of oxide flux does not significantly affect the hardness of type 316L stainless steel activated TIG weld metal.

2.5 Minimzing Work Efforts

Using of welding fixtures, which will help the welder to hold the job firmly and guide him to carry out the work with ease. Welding position decides the easiness of deposition of weld metal. A deposition which is made in down hand position will have better quality, bead shape and requires lesser effort from the welder. The same if it is carried out in overhead position it will affect not only the deposition rate, but also the quality, work effort, etc...The size of molten weld poll dictates the current that can be used for position welding [15]. Thus, while the maximum current which can be used in down hand welding position is limited generally only by the material and its thickness, the maximum current usable for positional welding is severely limited by the effect of gravity on the molten pool. An authoritative welding hand book says that if the welding costs are taken as 100 % in the down hand position, they rise to 165 % in the horizontal to 294% in the overhead position.

Sun and Kuo [16] have presented a dual-torch arc welding technique (plasma torch followed by a Gas Tungsten Arc torch) to improve productivity of Duplex stainless steel. It was found that by using dual-torch technique, undercut produced by keyhole plasma welding can be abated by the GTA arc remelting, thus produce a better weld profile. The corrosion rate increase with increasing torch pitch and or decreasing GTA arc remelting current. By adjusting the torch pitch, modification of weld microstructure may be realized. The present study demonstrated the potential of using dual torch technique to overcome undercut problem in keyhole plasma welds and to improve weldability and productivity of duplex stainless steel.

2.6 Minimizing Motion and Delays

Focusing on eliminating the unnecessary activities, excess motion, repeated movements, delay/waiting time etc...will enable better work centre planning and control. The use of jigs and fixtures or positioners enables the job to be done in down hand position welding. In addition, down hand welding with the use of manipulators or positioners calls for less skill on the part of the operator. It is also less fatiguing. Welding Hand Book-Published by the AWS [17] have presented that the Jig and Fixture also helps in minimizing distortion and the consequent rework. Working towards achieving the above simple objectives will results in enhanced productivity without making any change in the welding process, equipment, consumables, etc...But with little modification in the welding practices and by training of welders the required quality can be achieved.

2.7 Waste and Waste Reduction

In any ideal system the output is equal to input, but in actual conditions, Output = Input – Waste. It will be clear that to match the output to the input; the waste component should be reduced. Therefore to improve the productivity, one should look in to the waste component, which affects the output. A focused approach on waste minimization or elimination will result in improved output and or reduced input. Both ways, it will help us to enhance the productivity.

3. IMPROVING WELD PRODUCTIVITY

Young et al. [18] has presented that the α/γ ratio in the Duplex Stainless Steel fusion zone was drastically increased after laser welding .Preheating before welding DSS or changing the plasma-assisted gas from He to N_2, especially for later, could raise the γ content of the fusion zone. Impact toughness of the fusion zone increased with rising γ content .Meanwhile, the effect of N addition during laser welding also improves the welds ability to resist impact fracture. The Notched Tensile Test of the specimen in air increases with increasing content in the DSS fusion zone. As awhole, all the specimens were susceptible to gaseous hydrogen embrittlement but to different degree. Hydrogen embrittlement susceptibility is more obvious for the specimens containing a greater amount of α phase. The following illustration will be more helpful to understand the way to improve the productivity.

3.1 Weld Design

The designer should design the joint so that the minimum amount of weld metal is being deposited. An Unnecessary increase in the filet size from 6 mm to 8 mm can cause a consequent increase in the labour costs. The joint can be kept as few as possible by using standard rolled sections. Weld design is based upon this principal of minimum weld metal that the joints of higher thickness are designed as' K' welds, 'j' welds, etc. Design the weld sizes depending upon the load the weld metal is to carry. There may be many parts in the machines that are lightly loaded or not loaded at all and it may be wasteful to deposit full strength welds on these parts. Tables 7 and 8 show the weld metal cost for different types of electrodes.

Table 7: weld metal cost for different types of electrodes-a typical comparison

S.No	Electrode Type	Metal Recovery Rate	Price for 1000 No (Rs)	Weld Metal for 1000 pieces Kg	Cost of weld metal (Rs/kg)
1	General purpose Rutile	90	1112	35.3	31.50
2	Low Hydrogen Iron Power	115	1774	45.0	39.42
3	Rutile Iron power	140	2033	54.9	37.03
4	Rutle Iron power	210	2909	82.3	35.35
	All electrodes are 4 mm diameter and 450 mm long stub thrown away is 50 mm.				

3.2 Selection of Right Type of Electrode

The welding Institute,Cambridge [19] has reported that The ratio of the weight of deposited metal to the net weight of the electrodes consumed is known as Metal Recovery (MR).To achieve maximum welding productivity or in other words to reduce welding costs. It is not sufficient to judge the economics of an electrode merely from the price list. The Iron Powder Electrodes having higher Deposition Efficiency should be used. These electrodes contain an appreciable quality of metal power in the coating, such that the resulting deposit is more than that of the weights of the core wire melted.

Table 8: weld metal cost for different types of electrodes-a typical comparison

S.No	Electrode	Melting time per electrode Mins	Matl.cost of weld metal Rs/Kg	Labour cost of weld metal Rs/Kg	Total cost of weld Metal Rs/Kg
1	General purpose Rutile	1.90	31.50	8.24	39.74
2	Low Hydrogen Iron Power	1.70	39.42	5.80	45.22
3	Rutile Iron Power	1.85	37.03	5.16	42.19
4	Rutile Iron Power	2.15	35.35	4.20	39.55

The labour cost per Kg of weld metal are calculated from the melting time per electrode, arc time required to deposit 1 Kg of metal, weld time factor of arc time factor LOC's as Rs.4/hour and the arc time factor as 2.4, the costs for the four electrodes have been related and given in the column number 5 of above table. The total cost of weld metal is given in the last column.

Arc Time Factor (or) Weld Time Factor is defined as the ratio of Arc Time to total Welding time. The fact that items number 4, which is the most expensive electrode in the price list, works out most economical may seem astonishing. There are further advantages in using such high deposition efficiency electrodes. Suppose a fabricating shop employs 100 welders each of whom consumes 100 pieces of item number 1 in an 8 hour shift. This means that 353 Kgs of weld metal is deposited in a shift to maintain the production schedule. If the shop changes over to item number 3, only 64 welders would be required to give this output. If it changes over to 4, only 43 welders need be employed. Fewer welders means fewer welding machines, reduced maintenance cost, saving in floor space, fewer welding accessories and a smaller electric load ect. Table 9 show the type of electrode compositions for welding duplex stainless steel material.

3.3 Largest Size of Electrode to Be Used

The diameter of the electrode used has a great bearing, on productivity. The time of fusion of the electrode or the arcing time depends very much on this. Table 10 gives, at rated currents, the deposition rates of the coated electrodes of different diameter.

Table 11 shows that how much time is gained or lost by using large or smaller diameter electrodes. The figure along the diagonal read 1.00.All the figure above the diagonal are more than 1, and all the figure below the diagonal is less than 1.From 4th column and 4th row, we find the value to be 1.00.The values above this are 1.32,2.07,2.22 respectively.This means that instead of 4.00 mm diameter electrode, if we use diameter 3.25 electrode,the time will increase by 32 %.If a 2.5 mm electrode is used instead of 4.00 mm electrode, the time will increase by 107 %. Instead of using 4.00 mm electrode if we use 5.00 mm electrode, the time will be only 71.4% or saving of nearly 30%.A further advantage resulting from changing over to large diameter electrodes from the lower diameter electrode is the reduction in number of times required for changing the electrodes. By reducing the number of change, we can reduce the number of starts or stop and related issues as well as control the total heat input to the weld.

Table 9: Filler metal composition for duplex stainless steel (DSS)

Classification	C	Mn	Si	Cr	Ni	Mo	N	S	P	Cu	N	Al
E 2209-17	0.03	0.8	0.9	22.5	9	3.2	0.15					
E 308L-16	0.03	0.8	0.9	19.8	10.2							
Filler Metal	0.022	1.35	0.28	17	11.52	2.10						0.014
ER 2209	0.009	1.57	0.39	22.25	8.55	3.29		0.001	0.008	0.10	0.10	
ER2594	0.03	0.73		25.9	9.2	4.2	0.22	0.002	0.001	0.54		
AWS E 316L	0.020	1.80	0.07	18.70	11.7	2.70						
ER 2209 Duplex	0.030	1.50	0.90	23	9.50	3.0						
ER 2209 GRD 5.9	0.13	1.75	0.41	22.7	8.7	3.2	0.17	0.002	0.015			
Tech 2209	0.02	1.65	0.52	22.4	8.9	3.3	0.16					
ER 312 AWS A 5.9.	0.11	1.60	0.40	29	9.25	0.15		0.013	0.013			
The balance is Fe												

Table 10: Rate of deposition of electrode in different diameters

S.No	Diameter Of Electrode(mm)	Rate of Deposition gm / Average Minute.
1	2.00	11.4
2	2.50	12.2
3	3.25	19.2
4	4.00	25.3
5	5.00	35.5
6	6.30	51.5

Table 11: Arc time and diameter of electrodes

Diameter of the Electrode(mm)	Increase /Decrease in Arcing time with respect to diameter of electrodes)					
	2.00	2.50	3.25	4.00	5.0	6.30
2.00	1.00	1.07	1.69	2.22	3.12	4.50
2.50	0.935	1.00	1.58	2.07	2.92	4.23
3.25	0.590	0.632	1.00	1.32	1.65	1.85
4.00	.0450	0.483	0.756	1.00	1.40	2.04
5.00	0.320	0.342	0.540	0.714	1.00	1.45
6.30	0.22	0.238	0.973	0.490	0.63	1.00

Riad Badji et al. [20] have presented an experimental work that the TIG welding of 2205 duplex stainless using ER 2209 filler metal of 2.5 mm diameter, interpass temperature 120^{0}C, 15 Voltage, 115 Amperage resulted in a significant variation in the ferrite-austenite balance in the HAZ and fusion zone compared to the base metal. An increase in annealing temperature cause change in the toughness and tensile properties has been observed as a consequence of precipitation phenomena or an increase of ferrite content. The optimal combination of mechanical properties was obtained when precipitation of sigma and the γ-to-δ ferrite transformation are suppressed, i.e., at 1050^{0}C. Table 12 show the number of changes per kg of deposit for a rutile electrode.

Table 12: electrode diameter and electrode changes for making 1 kg of weld [21].

Electrode Size dia (mm)	Electrode Length	No.of Electrode changes per kg.of deposited weld metal
3.15	450	36
4.00	450	24
5.00	450	14
6.30	450	11

Ravichandran et al. [22] have presented that the addition of iron power in electrode coatings can be anything from a few percent up to more than 60 %.In some metal cored wires, iron power can account for up to 80 % of the core material. For coated high efficiency electrodes such as the rutile AWS E 7024,the basic AWS E 7028 and the acidic AWS E 7027,all characterized by the large amount of iron powder in the coating, range of coarse high apparent density powders are used. Among various types of electrodes specified in AWS 5.1 the coated iron power content may vary as show in table 13.

Table 13: type of electrodes specified in AWS 5.1 with the coating iron powder content

AWS 5.1 CLASSIFICATION	MAIN COATING CONSTITUENT	TYPICAL COATING IRON POWER CONTENT, WT %.
E 6010	CELLULOSE	10
E 7014	RUTILE	20-30
E 7024	RUTILE	30-60
E 7018	BASIS COATING	30
E 7028	BASIC COATING	30-60

3.4 Deep Penetration Electrode

The productivity of a deep penetration electrode is derived from the fact that a butt joint can be made in plates upto 12 mm thickness with square edges by depositing one pass on each side. The need for edge preparation is eliminated. Square edges ensure easy and accurate fit-up and root gap. Very little weld metal is required for fill the gap since a large proportion of the welded joint is made-up of the fused parent metal. Also back gauging operation is dispensed with. The type of electrode used in India has an extremely heavy coating which consists mainly of Rutile Iron Power and cellulose. It is made 350 mm long. It can carry very high current: 3.15 mm diameter-170 amp, 4.00 mm diameter225 amp, 5.00 mm diameter-300 amp. The penetrating arc lifts-up all the slag inclusions and gives a smooth weld metal with complete fusion.

4. CONCLUSION

The objectives briefed here as well as the typical tips will enlighten the ways to improve productivity.But, one has to remember that productivity is linked to the mind and attitude of people concerned.

1. Achieving the above goals could be accelerated by having a motivated team. A motivated team can make the difference and achieve the results.Therefore, creating a motivated team is the first step towards the journey for enhanced productivity.
2. This paper shows clearly that productivity and quality of DSS weld increase by selecting a right type of electrode and the best type of welding technique with optimal input parameter.
3. The rate of DSS weld metal deposition increase by maintaining optimal arc time and increasing the diameter of electrode. Deep penetration and narrow bead width occurs by connecting Direct Current Electrode Negative (DCEN) Straight polarity, constant current, constant melting rate.
4. The productivity, Economy and quality of weld metal mainly depends upon the skill and commitment of the welders of manual welding techniques.

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